R. 1.53(b) Continuation
of S. N. 09/953,954

IN THE SPECIFICATION:

Insert as the very first paragraph the following:

This application is a continuation of application Serial No. 09/953,954 filed September 18, 2001, which in turn is a continuation of application Serial No. 09/318,265 filed May 25, 1999, now Patent No. 6,352,756.

Change page 1, lines 8-16, to read:

The present invention relates to a honeycomb structure ~~to be suitably used~~ for use **as a catalyst carrier for purifying automobile exhaust gas. More particularly, the present invention relates to a thin-walled honeycomb structure that has thin partition walls, a light weight, a small loss of pressure, and an improved mechanical strength**. All improvements result **by virtue of reinforcing a circumferential portion of the honeycomb structure**, thereby preventing damage ~~not so as to give the damages~~ **to the honeycomb structure during its manufacturing or its handling**. ~~, and~~ The invention relates to **a method for reinforcing such a thin-walled honeycomb structure.**

Change page 2, line 2, to page 8, line 23, to read:

More concretely, a honeycomb structure has usually been produced by the steps of extrusion-molding a material, which mainly becomes cordierite when it is fired, through a nozzle having lattice-like slits so as to form integratedly a honeycomb portion and a circumferential wall, and subsequently drying and firing the thus molded article. ~~Thus~~ The obtained honeycomb structure is transferred to a step of forming the catalytic layer by first ~~firstly~~ coating the inner surfaces of numerous cell passages with γ-alumina so as to form a γ-alumina layer thereon, and then loading a noble metal component, as a catalytic component, such as platinum, rhodium, or palladium into inner surfaces of pores of thus formed γ-alumina layer. Then, the honeycomb structure is subjected to a baking treatment at a temperature of about 600°C so as to back the catalytic component thereon to give a catalyst for purifying exhaust gas. ~~Thus produced~~ The resulting catalyst for purifying exhaust gas is housed in a metallic container with the

aid of a cushioning material. The metallic container, i.e., a converter is connected to an exhaust pipe by means of welding, bolting, or the like, to set up an engine for an automobile, etc.

Regulations ~~Recently, regulations~~ on exhaust gases have become stricter ~~strict~~ year by year, especially in developed countries, due to ~~in consideration of~~ environmental problems. To cope with these stricter regulations, an ever-lasting improvement in purification ability is required for a catalyst for purifying exhaust gas. On the other hand, a desire to lower fuel charge and increase output of power has been evident in the fields of engine development. Because of such a situation, the reduction in pressure loss during operation has been required in the case of the catalyst for purifying exhaust gas. In the case of the catalyst for purifying exhaust gas, so as to solve the problems mentioned above, there ~~have~~ has become evident such a strong movement that the improvement in the performance of the catalyst for purifying exhaust gas at the time of warming ~~warning~~ up of the engine has been tried by increasing a passage area of the cell passages so as to reduce pressure loss. Furthermore, ~~and~~ lightening the weight of

the catalyst for purifying exhaust gas itself has been undertaken so as to reduce its heat capacity by making the partition walls thin without decreasing the number of cells as well. Hitherto, a honeycomb structure having partition walls of 0.15 mm or more ~~in the thickness~~ thick was most popular. However, a honeycomb structure having partition walls having a thickness of 0.13 or less, particularly, 0.11 mm or less, ~~in the thickness~~ has recently come to be popular.

However, to make partition walls of a honeycomb structure thinner causes a problem that the extremities(hereinafter sometimes referred to as a corner) of circumferential portions of the honeycomb structure are often broken during manufacturing, handling, or conveying the honeycomb structure, or housing the honeycomb structure into the container for converter so as to set it in an engine because the structural strength of the honeycomb structure is consequently decreased, particularly in the circumferential portions of the honey-comb structure. This phenomenon becomes evident when the partition walls of the honeycomb structure ~~becomes~~ become thinner. This is because damage

occurs ~~damages have recently come to be caused~~ in a honeycomb structure more frequently when ~~in accordance with thinning of~~ partition walls in a honeycomb structure are thinned. Note that the honeycomb structure is liable to break when an external force such as a mechanical shock is applied thereto during transportation or the like, even in the case of the honeycomb structure having thicker partition walls. This ~~is~~ potential breakage occurs because a ceramic material is inherently brittle. Thus, the breaking of the honeycomb structure was also occasionally reported. Because of its very low frequency of occurrence, however, it has not particularly been regarded as a problem.

Further, the frequency of the deformation in partition walls during extrusion-molding has remarkably increased as partition walls become thinner; while in the case of ~~the~~ conventional honeycomb structures having ~~such thicker~~ partition walls ~~as the thickness of~~ that are 0.15 mm or more thick, such a problem is ~~no~~ not so serious. This is because the circumferential wall has a thickness of at least 0.3 mm, and therefore, the strength in the circumferential portion can be ensured to a certain degree. The

deformation in partition walls occurs mainly ~~tends to be caused particularly~~ at the vicinity of the circumferential walls in the circumferential portions. This deformation is due to ~~Its major cause is considered to be~~ the failure to attain uniform extrusion-molding because of the unbalance in the fluidity of ~~a~~ raw material between the honeycomb portions and the vicinity of the circumferential partition walls, ~~in the case where~~ when the circumferential walls are ~~made~~ thicker than partition walls. Such thickening ensures ~~in a honeycomb structure so as to ensure~~ strength in the ~~a~~ circumferential portion.

A similar phenomenon when using ~~to the case where~~ cordierite to deform ~~is used in the deformation of~~ the partition walls ~~in the honeycomb structure~~ is also observed when a ceramic material such as alumina, mullite, silicon nitride, silicon carbide, or zirconia is subjected to an extrusion-molding. This phenomenon occurs ~~is~~ because, as a starting material, a material prepared by mixing and kneading ~~said~~ the starting material with water and a binder is used as well. Since the deformation in partition walls is mainly attributed to buckling derived from compressive load, a similar

problem is also observed in not only a honeycomb structure having square cells, but also in a honeycomb structure having a rectangular, triangular, or hexagonal shape.

Some proposals have been made to solve the various problems ~~derived~~ caused by making partition walls thinner in a honeycomb structure. First ~~Firstly~~, it has been proposed to reduce ~~make the thickness of~~ the circumferential walls from 0.3 mm to 0.1 mm. Thus, ~~so as to near~~ the thickness of the circumferential walls approximates the ~~to a~~ thickness of the partition walls, thereby improving ~~in order to improve~~ the balance in the flow amount of ~~a~~ raw material during molding. In this case, however, the strength of ~~in~~ the circumferential wall is not sufficient. In other words, when circumferential walls are too thin, ~~a~~ breaking starts at the circumferential walls due to ~~its~~ insufficient rigidity. A circumferential wall ~~The~~ thickness of at least 0.1 mm, desirably at least 0.15 mm, is sufficient just to house the honeycomb structure in ~~into~~ a container kept under a uniform and static external pressure ~~as a thickness for circumferential walls~~. However, such a circumferential wall thickness ~~for the circumferential walls~~ is not

sufficient to resist ~~against~~ external pressure, such as ~~a~~ mechanical shock ~~given~~ during transport ~~transporting the honeycomb structure~~ or the like.

On the other hand, ~~there has been made such a proposal~~ it has been proposed that the strength against mounting pressure of the circumferential walls would increase if ~~the thickness of~~ the circumferential walls are thickened ~~is made thicker~~. Thus, a cordierite honeycomb structure having square cells, a partition wall thickness of 0.11 mm, and a circumferential wall ~~such a~~ thickness of at least 0.4 mm ~~as circumferential walls~~ was prepared so as to increase strength. Contrary ~~On the contrary~~ to expectation, however, it was found, as a result of an isostatic strength test, that the honeycomb structure was not improved in strength and had a tendency of deterioration in strength. ~~The~~ An investigation was made ~~so as~~ to clarify ~~the reason~~ why the isostatic strength could not improve when only the thickness of the circumferential walls was made thicker. As a result, it has been found that partition walls (ribs) around cells in the circumference in a molded article are deformed to a great extent just after

extrusion- molding, and that the number of deformed partition walls increases as the circumferential wall is made thicker.

If ~~This is because, if~~ the circumferential wall is thickened, the ~~made thicker, an~~ amount of ~~a~~ raw material passing through slits for forming the circumferential walls increases when the raw material passes through slits of the nozzle upon extrusion-molding. As a consequence, partition walls around circumferential cells are ~~dragged~~ pulled toward the circumferential walls, or the circumferential walls press the internal partition walls of the honeycomb structure. Thus, it has been evident that the remarkable gap in the unbalance between a flow of the raw material for the circumference wall and a flow of the raw material for the partition walls is considered to be a major cause. Further, the thinning of the partition walls brings buckling deformation more easily. In addition, the circumferential wall and partition walls in the circumferential portion are deformed by the weight of the honeycomb structure itself at the time when a honeycomb structure is supported by a jig on the surface of the circumferential walls

right after extrusion-molding. These are also considered to be the ~~major~~ main causes.

If the internal partition walls of the honeycomb structure ~~is~~ are molded straight, the breakage of the honeycomb structure starts owing to the compression of the partition walls when pressure is ~~given~~ applied to the honeycomb structure from the surface side of the circumferential wall. This is because the internal portion of the honeycomb structure is theoretically the center of compressive stress. However, in the case where ~~that~~ partition walls at the vicinity of the circumferential portion are ~~is~~ deformed, or when ~~that~~ the circumferential wall is extremely thin, bending stress, i.e., a tensile stress, is generated at the position of partition walls of the honeycomb structure. Since the ~~a~~ ratio of tensile strength to compressive strength is generally as low as about 1:10, the honeycomb structure starts to break if it has deformed partition walls when even only very ~~lower~~ low strength is given thereto.

On the other hand, even if the circumferential wall can be ~~made~~ considerably thickened ~~thick~~ at the time of molding, a great

difference in heat capacity exists between the honeycomb portion having thin partition walls and the thick circumferential wall, thereby lowering ~~the~~ thermal shock resistance of the honeycomb heater ~~is lowered~~.

In order to solve the problems derived from an extreme difference in thickness between the honeycomb portion and the circumferential portion, ~~there has been made~~ the following proposal has been made; a molding is carried out, with ~~the~~ adjustment of a raw material flow at the time of extrusion, by making partition walls in the circumferential portion and the circumferential wall thicker ~~so as~~ to enhance pressure resistance in an axial direction of the honeycomb structure and ~~a~~ molding is carried out by adjusting. However, since the adjustment of balance is very subtle when this means is used, it becomes more difficult to suppress deformation in the partition walls as the circumferential wall becomes thicker. Furthermore, the thicker circumferential portion ~~gives~~ has a greater influence on its own heat capacity. In this case, the temperature difference ~~in temperature~~ between the inside and the outside of the circumferential wall increases ~~is increased~~;

thereby thermal shock resistance of the honeycomb structure ~~as~~ inevitably decreases ~~decreased~~. Furthermore, since such means brings about an increase in weight of the honeycomb structure, the performance of the catalyst after ~~of~~ an engine is warmed up is lowered. Furthermore, it is not so preferable due to the pressure loss problem.

Change page 10, lines 7-22, to read:

The present invention has been made, taking into consideration the aforementioned conventional problems. Thus, the aim of the present invention is to provide a honeycomb structure having not only sufficient catalytic properties, mechanical strength, and thermal shock resistance, but also having a reinforced circumferential portion that is not ~~so as to be~~ damaged during manufacturing or handling the honeycomb structure. According to the present invention, there is provided a thin-walled honeycomb structure comprising:

a circumferential wall,

numerous partition walls disposed inside ~~the~~ **circumferential wall** cage portions, defined by the partition walls meeting the circumferential wall, **and**

numerous cell passages defined by the partition walls and a coat of reinforcing material covering the circumferential wall;

wherein a circumferential portion of the honeycomb structure is reinforced wholly or in ~~a~~ **part within a certain distance from an extremity surface of the honeycomb structure by a reinforcing material** ~~which~~ that **dissipates, or** ~~evaporate~~ evaporates **at a high temperature**, thereby protecting the edge portions of the honeycomb structure from damage before the structure is fired.

Change page 11, lines 8-18, to read:

According to the present invention, there is further provided a method for reinforcing a thin-walled honeycomb structure comprising:

presenting a honeycomb structure having **a circumferential wall,**

numerous partition walls disposed inside the circumferential wall, and

numerous cell passages defined by the partition walls;

wherein a circumferential portion of the honeycomb structure is coated wholly or in ~~a~~ **part within a certain distance from an extremity surface of the honeycomb structure with an organic high molecular** weight **material.**

Change page 12, line 22, to page 13, line 11, to read:

Fig. 1 is a perspective view showing an unreinforced ~~embodiment of a~~ **thin-walled honeycomb structure**; ~~of the present invention~~

Fig. 2 is a view of the presently claimed invention according to examples 1-4;

Fig. 3 is a view of the presently claimed invention according to examples 5 and 6; and

Fig. 4 is a view of the presently claimed invention according to examples 7-14.

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Detailed Description of ~~Mode for Carrying Out~~ the Invention

A thin-walled honeycomb structure of the present invention has the same structure and basic shape as a conventionally known general honeycomb structure 1. As shown in a perspective view of Fig. 1, the thin-walled honeycomb structure is constituted by a circumferential wall 2, numerous partition walls 3 disposed inside the circumferential wall 2, and numerous cell passages 4 (cells 4) defined by the partition walls 3. Though each of the cells 4 has a square shape (sectional shape) in Fig. 1, it may also be triangular, rectangular, hexagonal, circular, or the like.

Page 19, line 4, cancel the title ~~Example~~ and replace with: Examples

Change page 21, line 11 to page 23, line 1, to read:

Fig. 2 illustrates ~~In each of the~~ **Examples 1 and 2,** in which **the surface of the circumferential wall 2 was impregnated with a resin** 6. **A mixture liquid having an adequately low viscosity was prepared by mixing a polyamide curing agent, a solvent, and a plasticizer with a commercially available epoxy resin. A honeycomb structure in which the entire surface of the end was masked with a tape was immersed in the liquid** ~~by about~~ approximately **10 mm from its** ~~extremity~~ end surfaces, leaving a band of uncoated surface 5, **so that the circumferential wall of the honeycomb structure was impregnated with the liquid. After the surface of the circumferential wall was coated with the resin liquid to a certain degree, the honeycomb structure was taken out, and the resin liquid sticking to the circumferential wall was wiped off. The honeycomb structure was put in a drying container** ~~so as~~ **to be subjected to a thermal curing treatment at about 150°C for 30 minutes**, thereby producing a resin reinforced honeycomb structure 20.

In Examples 3 and 4, both shown in Fig. 2, **a resin** 6 **was applied on the circumferential wall** 2. **An adhesive** ~~which~~ that **had been prepared by mixing a nitrile rubber with a commercially**

available thermosetting phenol resin was applied on the circumferential wall, thereby forming an adhesive layer having a thickness of 1 - 2 mm and a width of approximately 10 mm from the end surfaces of the honeycomb structure ~~was formed~~ over the whole circumference of the circumferential wall in a narrow band. Then the honeycomb structure was subjected to heat-curing treatment at about 180°C for 30 minutes, thereby producing a resin reinforced honeycomb structure 20.

Fig. 3 illustrates ~~In~~ Examples 5 and 6, in which a resin was filled into cells in the circumferential portion. First, a mixture liquid having an adequately low viscosity was prepared by adding a polyamide curing agent, a solvent, and a plasticizer to an epoxy resin. A honeycomb ~~heater~~ structure whose end surfaces were ~~extremity was~~ masked with a tape ~~so as~~ to exclude cells in the most circumferential portion was immersed in the liquid ~~by about~~ to a depth of approximately 10 mm. After the liquid was filled into the circumferential cells 7, the honeycomb structure was taken out. The liquid sticking to the surface of the circumferential wall was wiped off. Then, the honeycomb structure was put in a drying

container and subjected to a heat-curing treatment for about 150°C for 30 minutes, thereby producing a resin circumferential cell and surface reinforced honeycomb structure 30.

Fig. 4 illustrates ~~In~~ Examples 7 - 14, in which a tape 8 was put on the surface of the circumferential wall 2. A rubber pressure-sensitive adhesive was applied on one side of a thin sheet. An adhesive tape having a thickness of 1 - 2mm was cut ~~so as~~ to have a width of approximately 10mm. The tape 8 was wound around the circumferential wall by ~~with~~ being pressed against the surface of the wall to cover the range within approximately 10mm from the end of the honeycomb structure, thus leaving an uncoated surface 5. This treatment results in a tape reinforced honeycomb structure 40

Page 23, after line 16, insert the following:

The following is a summary of the reinforcement of the circumferential portions in Table [illegible]

Comparative Example 1:

The cell passages on the circumferential portion and the circumferential wall were filled with a ceramic until the depth of approximately 10 mm from the end surface. The resultant was refired.

Comparative Example 2:

A ceramic was immersed at the circumferential wall of the structure up to the distance of approximately 10 mm from the end surface. The resultant was refired.

Comparative Examples 3 to 6:

No reinforcement

Comparative Examples 7 and 8:

A ceramic was immersed at the circumferential wall of the structure up to the distance of approximately 10 mm from the end surface. The resultant was refired.

Examples 1 and 2:

A resin was immersed at the circumferential wall of the structure up to the distance of approximately 10 mm from the end surface. The resultant was subjected to curing of the resin.

Examples 3 and 4:

A resin was coated at the circumferential wall of the structure up to the distance of approximately 10 mm from the end surface. The resultant was subjected to curing of the resin.

Examples 5 and 6:

The cell passages on the circumferential portion of the structure were filled with a resin to a height approximately 10 mm from the end surface. The resultant was subjected to curing of the resin.

Examples 7 and 14:

An adhesive tape was adhered on the circumferential wall of the structure, the tape width being approximately 10 mm from the end surface.